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Invasive Marine and Estuarine Animals of the Pacific Northwest and Alaska

by Gary L. Ray

PURPOSE: New species of estuarine and marine animals are inadvertently or intentionally introduced into the waters of the United States every year (Figure 1). Variously referred to as introduced, nonindigenous (NIS), alien, nonnative, or exotic species, most pose little or no threat; however, a few have the potential to disrupt local ecosystems, fisheries, and human infrastructure. Such invasions directly impact the mission of the U.S. Army Corps of Engineers (USACE) through its responsibilities for construction and maintenance of harbors, ports and waterways, erosion control, management of water resources, and wetland and coastal habitat restoration. The general biology and ecology of invasive estuarine and marine animals have been described in previous works (Carlton 2001, Ray 2005). This report is part of a series describing the biology and ecology of known invasive estuarine and marine animals in the major geographic regions of the United States. Invasive animals of the Pacific Northwest and Alaska are described and species that pose a specific threat to USACE activities are identified.

BACKGROUND: Invasive species are officially defined as "alien species whose introduction does or is likely to cause economic or environmental harm to human health" (Executive Order 13112, Federal Register 1999). Any species removed from its native range has the potential to become invasive. This is because within its normal range, predation, disease, parasites, competition, and other natural controls act to keep population levels in check (Torchin et al. 2003, Wolfe 2002). Once released from these controls, species abundances have the potential to reach levels that interfere with or displace local fauna. Such effects may occur immediately, after some period of delay, or never be realized at all depending on the characteristics of the individual species and the conditions into which it is introduced.

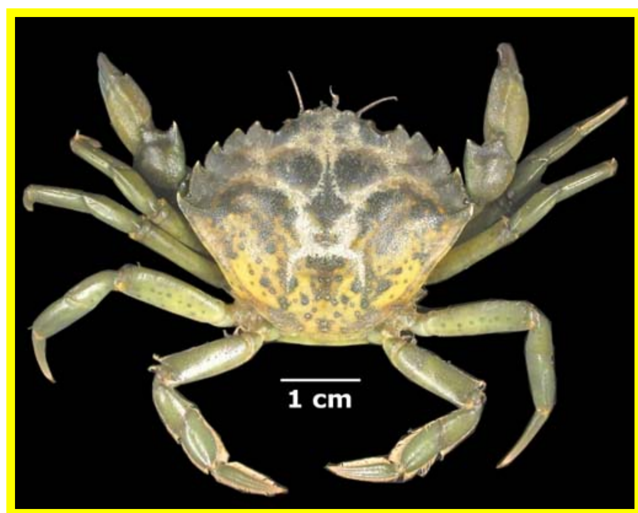

Figure 1. Example of an invasive species, the European green crab, *Carcinus maenas* (image courtesy of California Academy of Sciences)

Lists of estuarine and marine nonindigenous species are often dominated by molluscs, crustaceans, and polychaete worms; however, this may reflect their ease of identification and detection rather than the degree to which they are representative. Ultimately it is an organism's biological characteristics (e.g., reproductive capacity, growth rate) and not its taxonomic affinities that determine if it becomes invasive. Successful invaders tend to be those that are abundant over a large

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range in their native region, have broad feeding and habitat preferences, wide physiological tolerances, short generation times, and high genetic variability (Erlich 1989, Williams and Meffe 1999). Despite the fact that these characteristics can be identified, predicting which species pose the greatest threat remains problematic since many species possess these characteristics, most are not obvious in their native range, and the opportunities for introduction and subsequent likelihood of survival are difficult to assess. The situation is further complicated by difficulty in distinguishing invaders from species with naturally wide distributions and those that are cryptogenic; that is, species whose original distributions are uncertain.

Predicting which habitats are likely to be invaded is much simpler. Invaded habitats tend to have low natural diversity, relatively simple (low-connectance) foodwebs, and a history of recent natural or anthropogenic disturbance (Williams and Meffe 1999). Estuaries and sheltered coastal areas are among the most invaded habitats, presumably due to the fact that they are naturally disturbed, low-diversity systems and are historically centers of anthropogenic disturbance associated with navigation, industrial development, and urbanization.

Most estuarine and marine species introductions are associated with shipping (Ruiz et al. 2000). Species capable of attaching to hard surfaces may be transported on ship hulls, navigational buoys, floatation devices, anchors, chains, ropes, and flotsam or jetsam (Carlton 2001). During the heyday of wooden-hulled ships, woodborers (e.g., shipworms) and species associated with "dry" ballast such as stones, rock, sand, or other materials were frequently introduced (Carlton and Hodder 1995). Presently, the largest single source of shipping-related introductions is ballast water (Carlton 1985, Lavoie et al. 1999). Ballast water is taken onboard vessels for a variety of purposes related to ship maneuverability and control (Carlton et al. 1995). Animals suspended in the water column or present in bottom sediments are taken in and then introduced to a new location when the ballast is pumped out.

Recently, concerns have also been raised with introduction of fish, invertebrates, and "live" rock from the aquarium trade (Padilla and Williams 2004, Weigle et al. 2005). Other introductions may result from accidental release of animals, inappropriate disposal of packing material by restaurants serving live seafood, and the live bait industry (Cohen et al. 2001a). Many species have been deliberately introduced to develop new fisheries. For example, the Atlantic striped bass *Morone saxatilis* has been introduced both outside its normal geographic range and in nonnative habitats (e.g., reservoirs) throughout much of the United States.

METHODS: Lists of invasive species in the Pacific Northwest and Alaska were prepared by querying NISBase, a national database of NIS listings maintained by the Smithsonian Institution (*http://www.nisbase.org/nisbase/index.jsp*). Part of the National Exotic Marine and Estuarine Species Information System (NEMESIS), this database permits simultaneous searches of multiple NIS listings. Searches return up to 300 species and include links to individual species' fact sheets and collection data. Queries were performed by state and included searches of the U. S. Geological Survey's Nuisance Aquatic Species (NAS) database (*http://nas.er.usgs.gov/*) and Australia's National Introduced Pest Species Information System (*http://www.cmar.csiro.au/*). The resulting lists were examined and separate lists were prepared for estuarine and marine animals. Cryptogenic species were excluded from consideration due to the uncertainty of their origins. The NIS list was amended as necessary after comparison with individual state NIS listings and other reports (Table 1).

An excellent review of the NIS problem by Elston (1997) with special regard to the Puget Sound region is available online at *http://www.psat.wa.gov/shared/nis.html*. The State of Washington maintains a listing of marine NIS specific to the state and adjacent waters at *http://www.wdfw.wa.gov/fish/nuisance/ans4.htm*, while a similar list (Carlton et al. 2003) for Oregon waters can be found at *http://science.oregonstate.edu/~yamadas/*. The Prince William Sound Regional Advisory Board also maintains downloadable fact sheets describing the species of greatest concern in Alaskan waters (*http://www.pwsrcac.org/NIS/pws3.html*).

Table 1
State NIS Listings and Other Reports Utilized in This Report

Carlton et al. 2003
Cohen et al. 2001b
Cohen 2004
Hanson and Sytsma 2001
Hines and Ruiz 2000
Hines and Ruiz 2001
Mills 2003
State of Alaska 2002
State of Washington 2001
Wonham and Carlton 2005

RESULTS: NIS listings for the Pacific Northwest and Alaska included 162 species (Table 2). The largest number of species was found among the molluscs (47 species) and crustaceans (39 species) (Appendix A). Many of these represent species that were deliberately introduced such as the oysters *Crassostrea gigas*, *C. rivularis*, *C. virginica*, and *Ostrea edulis*; the Japanese littleneck clam *Venerupis (Tapes) phillippinarum*; the hard clam *Mercenaria mercenaria*, the softshell clam *Mya arenaria*; and the blue mussel *Mytilus edulis*. Introduced crustaceans include the shrimp *Palaemon macrodactylus* and *Exopalaemon modestus* and American lobster *Homarus vulgaris*. A number of fish were also deliberately introduced such as American shad *Alosa sapidissima*, gizzard shad *Dorosoma petenense*, Atlantic salmon *Salmo* salar, and Atlantic striped bass *Morone saxatilis*. The coho salmon *Onchorhynchus kisutch*, a native of the Pacific Northwest, has been stocked in so-called nonindigenous waters, i.e., waters where they do not naturally occur.

Several species may have been unintentionally introduced during shellfish introductions from both the Atlantic coast and Japan. Species associated with Atlantic oysters are slipper shells *Crepidula fornicata*, *C. convexa* and *C. plana*, Atlantic oyster drill *Urosalpinx cinerea*, boring-sponge *Cliona* sp., ribbed marsh mussel *Geukensia demissa*, Eastern mud snail *Nassarius obsoletus*, and the pileworm *Nereis succinea*. Species associated with Japanese oyster and Japanese littleneck clam plantings are the mussel

Table 2
Numbers of NIS in the Pacific Northwest and Alaska

Group	WA	OR	AK	Total for Region
Protozoan	1	1		1
Hydrozoan	5	6	1	8
Schyphozoan	1			1
Porifera	6	3	1	7
Anthozoan	1	3	1	3
Platyhelminth	2			2
Polychaete	13	16	2	21
Oligochaete	4	3		6
Bivalve	17	6	2	17
Gastropod	25	5		27
Nudibranch		1		1
Chiton	1			1
Barnacle	1	1		1
Copepod	7	7		10
Amphipod	10	9		11
Isopod	3	3		5
Tanaid	2	2		3
Cumacean	1	1		1
Crab	3	3		4
Shrimp	1	3		3
Lobster	1			1
Bryozoan	7	9		10
Entoproct	1	1	1	1
Tunicate	7	5	2	9
Fish	5	8	2	8
Total	125	96	12	162

Musculista sp., the parasitic copepod *Pseudomyicola (Myticola) ostreae,* and the Japanese false cerith *Battilaria attramentaria*.

Approximately 38 NIS species (24 percent of total) are associated with hard structures and may contribute to fouling. Probably introduced on ships' hulls or in ballast water, they include eight hydrozoans, seven sponges, three anthozoans (anemones), one barnacle, ten bryozoans, one entoproct, and nine tunicates. Only two of these species, the boring sponge *Cliona thoosina* and *Schizoporella unicornis*, a bryozoan, are considered to be species of concern.

Geographic distribution of NIS varies substantially among states, with Washington having the largest number (125 species) and Alaska the least (12 species). The relatively low number of NIS in Alaska waters has been attributed to a poor historical record from which to assess what fauna are native and the limited number and scope of biological surveys for NIS (Hines and Ruiz 2000).

DISCUSSION: Species identified as invasive or of concern in the state of Washington are European green crab *Carcinus maenas*, Chinese and Japanese mitten crabs *Eriocheir sinensis* and *E. japonicus*, Asian clam *Potamocorbula amurensis*, Japanese oyster drill *Ceratostoma inornatum*, Asian copepod *Pseudodiaptomus inopinus*, Mediterranean mussel *Mytilus galloprovincialis*, and Atlantic salmon (State of Washington 2001). Although the State of Alaska (State of Alaska 2002) officially lists only green and mitten crabs as species of immediate concern, the Prince William Sound Regional Advisory Board includes the foraminiferan *Trochammina hadai*, boring sponge *Cliona thoosina*, the capitellid polychaete *Heteromastus filiformis*, Japanese oysters (*C. gigas*), softshell clams, single-horn bryozoan *Schizoporella unicornis*, and Atlantic salmon on this list. Oregon specifically prohibits introduction of mitten crabs, Japanese oyster drills, and Asian clams (*P. amurensis* and its relatives) as well as the Atlantic blue crab *Callinectes sapidus* (Hanson and Sytsma 2001).

Potential Threats to Infrastructure. Several introduced wood-boring species are present in the Pacific Northwest, such as the shipworm *Teredo navalis* and the isopods *Limnoria tripunctata* and *Sphaeroma quoyanum*. *Teredo navalis*, a bivalve mollusc, is a threat to wooden structures including boats, marinas, docks, and pilings. It reportedly was responsible for $615 million in damage in San Francisco Bay during an outbreak in the 1920's (Cohen and Carlton 1995). Likewise, severe damage was reported in Barnegat Bay, New Jersey and Long Island Sound, New York after outbreaks of the closely related species *T. bartschi* (Hoagland 1983). These pests can be effectively controlled by chemical treatment (e.g., creosote) or use of alternative materials (Highley 1999). While creosote deters shipworm infestations, the same cannot be said of the marine isopod genus *Limnoria*, more commonly known as gribbles (Figure 2). Gribbles are able to burrow into treated wood and may even derive nutrition from bacteria in their gut that break down creosote hydrocarbons (Zachary et al. 1983). Recently, engineers with the City of Seattle have discovered that a seawall and its wooden supports along the Seattle waterfront have become so damaged by gribbles that the structure may collapse (Figure 2). Replacement costs have been estimated at $700 million (Roach 2004). Gribbles in the Pacific Northwest include both the native species *Limnoria lignorum* and the invasive Mediterranean gribble *L. tripunctata*. Maximum size of gribbles is approximately 4 mm (Kozloff 1983).

Figure 2. *Limnoria* sp. and the damage it can cause (images courtesy of Washington State Department of Transportation)

The Chinese mitten crab *Eriocheir sinensis* first appeared as an invasive species in Germany during the early 1900's and has since spread through most of Europe (Clark et al. 1998). It has been reported in the United States from Lake Erie, San Francisco Bay, the Columbia River, and Mississippi Sound. Mitten crabs are catadromous, spending most of their adult life in fresh water, then returning to the sea to reproduce. They form extensive burrows in riverbanks and levees, thus posing a direct threat to earthen water control structures. The life history of the Japanese mitten crab (*E. japonicus*) is believed to be similar. Further information on the life history of mitten crabs can be found either in Veldhuizen and Stanish (2002) or an ANS fact sheet (*http://el.erdc.usace.army.mil/ansrp/eriocheir_sinensis.htm*).

Potential Threats to Habitat Restoration. The European green crab *Carcinus maenas* (Figure 1) inhabits a wide range of habitats in sheltered areas including rocky intertidal, unvegetated intertidal and subtidal mud and sand, salt marsh, and seagrass. Capable of tolerating a wide range of salinity and temperature, it prefers mesohaline to polyhaline salinities (10-30 ppt) and temperatures between 3 and 26 °C (Grosholz and Ruiz 2002). The green crab was introduced to the east coast of North America sometime in the 1800's (Scattergood 1952) and subsequently invaded the west coast. It has been detected in San Francisco Bay (Cohen et al. 1995) and other California estuaries (Grosholz and Ruiz 1995). It has been reported as far north as Oregon (Miller 1996) and Vancouver Island, Canada (Yamada et al. 2001) and could move into Alaskan waters (Gray Hitchcock et al. 2003). Genetic studies show that invasion of the Pacific coast was from east coast populations (Bagley and Geller 1999) with secondary expansion along the west coast attributable to oceanic transport of the planktonic larvae (Yamada et al. 2001). Larvae take approximately 90 days to develop, metamorphose, and settle out in mussel beds, eelgrass beds, or patches of filamentous algae (Moksnes 2002). Older juveniles actively migrate to mussel beds. Juvenile green crabs feed primarily on detritus, then shift to algae, snails, bivalves, annelids, crustaceans, and other benthic organisms as they mature (Pihl 1985, Ropes 1968). Predation on both natural and cultured bivalve populations has led to declines in softshell clams in New England (Glude 1955), *Nutricola* spp. in Central California (Grosholz et al. 2000), and the venerid clam *Katelysia scalarum* in Tasmania (Walton et al. 2002, Ross et al. 2004). While the green crab may outcompete Dungeness crab *Cancer magister* for food, their habitats generally do not overlap (McDonald et al. 2001). Control measures

have generally been unsuccessful and limited to trapping. For more information on this species, see Ray (2005) and Grosholz and Ruiz (2002).

The Asian or Amur River corbula clam *Pomatocorbula amurensis* (Figure 3), a native of Chinese, Japanese, and Korean waters, inhabits both intertidal and subtidal mud and sand. It tolerates a wide range of salinities and temperatures and feeds on bacteria, phytoplankton, and copepod larvae (Cohen and Carlton 1995, Kimmerer et al. 1994, Werner and Hollibaugh 1993). Since its initial detection in San Francisco Bay in 1987 it has become the dominant infaunal species in the bay, displacing native fauna (Carlton et al. 1990, Nichols et al. 1990). It appears to be responsible for a significant decline in bay phytoplankton (Alpine and Cloern 1992), which in turn has had negative impacts on resident zooplankton and fish populations (Kimmerer et al. 1994, Feyrer et al. 2003). Although presently limited to San Francisco Bay, it has the potential for widespread distribution via planktonic larvae. This species may interfere with the natural recolonization of dredged material deposits or sediments employed in beneficial use projects.

Figure 3. *Potamocorbula amurensis* (image courtesy of California Academy of Sciences)

Mytilus galloprovincialis, the Mediterranean blue mussel, has been introduced to both west coast and Hawaiian waters (Eldredge and Evenhuis 2002). Currently found worldwide in temperate seas, it has been nominated as one of the “top 100 world’s worst invaders.” On the Pacific coast, its range extends from Coos Bay, Oregon to San Diego, California. This mussel has the potential to interfere with restoration of rocky intertidal habitats by excluding native species. The same may be true of the bryozoan *Schizoporella unicornis.* Introduced from Japan, it encrusts hard surfaces, excluding or inhibiting settlement by native species. The Prince William Sound Regional Advisory Board maintains a fact sheet containing additional information on this species (*http://www.pwsrcac.org/NIS/pws3.html*).

Of the several copepod species introduced along the west coast, the Asian species *Pseudodiaptomus inopinus* is most commonly listed as one of concern in the Pacific Northwest. Invading the Columbia River estuary sometime in the 1980’s, it is now established in the upper reaches of estuaries from Oregon to British Columbia. It can be the most abundant copepod present from summer to fall (Cordell and Morrison 1996, 1999; Cordell and Rasmussen 2001). There is concern that it may represent a less desirable food source for developing fish than native species. Meng and Orsi (1991) have suggested that the dominance of introduced copepods in Northern California bays, including the closely related invasive *P. marinus,* may have contributed to the failure of a year class of striped bass.

Sphaeroma quoyanum is a wood-boring marine isopod, similar in size and shape to the common garden pillbug, which poses a threat to marsh restoration efforts. Introduced from Australasia on ship hulls during the California gold rush, it can now be found from San Diego, California to

Coos Bay, Oregon. It burrows into a variety of substrates including wood, soft rock, and salt marsh peat (Talley et al. 2001). It prefers the salt marsh peat of *Salicornia* spp.-dominated marshes and is found predominately high in the intertidal zone on bay-front rather than creek edge marsh banks. It forms horizontal burrows on vertical and undercut banks, weakening them, eventually resulting in collapse and severe erosion. Burrow densities are vastly greater on vertical rather than sloping banks so it may be possible to limit its effects by incorporating sloped banks into salt marsh restoration designs (Talley et al. 2001).

Unintentional introduction of NIS during stocking of nonnative oysters has been identified by Wonham and Carlton (2005) as the single largest source of NIS in the Pacific Northwest. More than 20 percent of all marine and estuarine NIS are believed to have arrived with these shipments. Species of concern introduced with Japanese oysters (*C. gigas*) include the Japanese oyster drill *Ceratostoma inornatum*, the Japanese false cerith *Batillaria attramentaria* (= *zonalis*), and the Asian date mussel *Musculista senhousia*. As its name implies, the drill is an oyster predator that preferentially feeds on young oysters. It has been reported to prefer *C. gigas*, but will also eat native oysters such as *Ostreola conchaphila* (Buhle and Ruesink 2003). Like most muricid gastropods, the larvae are not planktonic so control is possible by quarantining infested oyster beds. Japanese false cerith has become the dominant snail species on many California and Pacific Northwest mudflats and salt marshes. Its ability to replace the native marsh snail *Cerithidea californica* has been attributed to resistance to parasites, lower mortality, greater tolerance of low oxygen conditions, and more efficient food conversion (Byers 2000a, 2000b; Byers and Goldwasser 2001). The Asian date mussel is native to intertidal and subtidal sediments from Siberia to the Red Sea and is now found in Australia, New Zealand, the eastern Mediterranean, and southern France (Crooks 1996). Probably introduced into the United States in 1924 during introduction of Japanese oysters to Samish Bay, Washington, it has since spread as far as Southern California most likely via ballast water. Its planktonic larvae can remain in the water column as long as 55 days before settling out on either muddy or sandy substrates. This species forms dense beds that significantly alter nearby sediments and native benthic assemblages (Crooks 1996, 1998; Crooks and Khim 1999). Since much of dredged material is comprised of soft sediments, this species may interfere with the natural recolonization of dredged material deposits or sediments employed in beneficial use projects. Transplantation success of seagrass restoration projects may also be reduced in infested areas (Reutsch and Williams 1998). Ironically, dense, intact beds of native seagrass directly inhibit the growth of *Musculista* populations by limiting delivery of phytoplankton within the bed (Allen and Williams 2003).

Species believed to have been introduced with Atlantic oysters (*C. virginica*) include the eastern mud snail *Nassarius (=Ilyanasa*) *obsoleta*, the Atlantic oyster drill *Urosalpinx cinerea*, and the ribbed mussel *Geukensia (=Ischadium) demissa*. *Nassarius* is presently distributed from San Francisco Bay to British Columbia (Cohen and Carlton 1995). Most abundant in salt marshes and tidal creeks (sloughs) it, like *Battilaria*, has displaced the native snail *C. californica* in many California salt marshes (Race 1982). *Nassarius* produces planktonic larvae capable of tolerating wide ranges of temperature, salinity, and oxygen concentrations (Vernberg and Vernberg 1975). Adults feed primarily on surface algae and other microorganisms (Scheltema 1964, Pace et al. 1979, Feller 1984), but the physical disturbance caused by their feeding activities and removal of algal cover can have a disproportionate effect on other infaunal populations. *Nassarius* has been shown to affect both larval settlement (Hunt et al. 1987, Dunn et al. 1999) and adult distributions of other

infauna (DeWitt and Levinton 1985, Kelaher et al. 2003). Like the Japanese oyster drill, the Atlantic oyster drill is a threat to both stocked and native oyster populations. It also has non-planktonic larvae and its spread can be controlled by quarantine of infected stocks. The ribbed mussel dominates marsh channel bank habitats in much of San Francisco Bay (Cohen and Carlton 1995). While its ecological impact is uncertain, its presence may threaten the endangered California clapper rail (*Rallus longiorostrus obsoletus*). It has been claimed that birds feeding on the mussel may become entangled in the mussels and either drown or lose their toes (Cohen and Carlton 1995).

Another species of concern associated with oysters is the boring sponge *Cliona thoosina*. The sponge encrusts the surface of mollusc shells, secreting enzymes that etch the shell. Once weakened, the shellfish are more vulnerable to predators. The sponge is suspected of being introduced either via ballast water or in shellfish shipments. The Prince William Sound Regional Advisory Board maintains a fact sheet containing additional information on this species at the website listed above.

The introduced Japanese purple varnish clam *Nuttalllia obscurata* is one of the dominant bivalves of intertidal sands from northern Washington to British Columbia (Byers 2001). It has a brown outer layer that peels off like old varnish and purple inner shell lining, hence its name (Mills 2002). Most likely introduced into British Columbia in ballast water during the 1980's, it is most abundant just below mean low water (MLW). Its success appears to be due to superior burrowing ability, since local predatory crabs prefer it to native species (Dudas et al. 2003). This species is actively harvested in its native range and some consideration is being given to establishing a fishery for it (Washington Department of Fish and Wildlife 2004).

Finally, the impact of Atlantic salmon *Salmo salar* escaping from mariculture facilities in British Columbia is a matter of vigorous debate (Volpe 2001). Escaped fish have been collected as far north as Alaska (Wing et al. 1992). Prior to introduction, it was assumed that escapees would not be able to survive, breed, establish viable populations, or compete with native species. Volpe et al. (2000) indicate that not only have escaped salmon survived, but they have also spawned in the rivers of British Columbia. There is also some evidence to suggest competition with native species (Volpe et al. 2001).

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REFERENCES

Allen, B. J., and Williams, S. L. (2003). “Native eelgrass *Zostera marina* controls growth and reproduction of an invasive mussel through food limitation,” *Marine Ecology Progress Series* 254, 57-67.

Alpine, A. E., and Cloern, J. E. (1992). “Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary,” *Limnology and Oceanography* 37, 946-955.

Bagley, M. J., and Geller, J. B. (1999). “Microsatellite DNA analysis of native and invading populations of European Green crabs.” *First National Conference on Marine Bioinvasions. January 24-27, 1999. Cambridge, MA.* Available online at: *http://massbay.mit.edu/exoticspecies/conferences/1999*.

Buhle, E. R., and Ruesink, J. L. (2003). “Context-dependent impacts of multiple invasive species and a threatened native species in a west coast estuary.” *Third International Conference on Bioinvasions. March 16-19, 2003*. Available online at *http://massbay.mit.edu/exoticspecies/conferences/2003*.

Byers, J. E. (2000a). “Competition between two estuarine snails: implications for invasions of exotic species,” *Ecology* 81, 1225-1239.

Byers, J. E. (2000b). “Differential susceptibility to hypoxia aids estuarine invasion,” *Marine Ecology Progress Series* 203, 123-132.

Byers, J. E. (2001). “Physical habitat property mediates biotic resistance to non-indigenous species invasion.” *Second International Conference on Marine Bioinvasions. April 9-11, 2001. New Orleans, LA.* Available online at *http://massbay.mit.edu/exoticspecies/conferences/2001*.

Byers, J. E., and Goldwasser, L. (2001). “Exposing the mechanism and timing of impact of nonindigenous species on native species,” *Ecology* 82, 1330-1343.

Carlton, J. T. (1985). “Transoceanic and intraoceanic dispersal of coastal marine organisms: the biology of ballast water,” *Oceanography and Marine Biology: An Annual Review* 23, 313-374.

Carlton, J. T. (2001). *Introduced Species in U.S. Coastal Waters: Environmental Impacts and Management Priorities*. Pew Oceans Commission. Arlington, VA. Available online at *http://www.pewtrusts.org/pdf/env_oceans_species.pdf.*

Carlton, J. T., and Hodder, J. (1995). “Biogeography and dispersal of coastal marine organisms: experimental studies on a replica of a 16th century sailing vessel,” *Marine Biology* 121, 721-730.

Carlton, J. T., Chapman, J., Yamada, S., Rumrill, S., Burke, J., Fleck, B., Howard, C., Hunt, C., and Palacios, K. (2003). *Introduced species in Oregon Estuaries*. Available online at *http://science.oregonstate.edu/~yamadas/*.

Carlton, J. T., Reid, D. M., and van Leeuwen, H. (1995). *Shipping Study. The role of shipping in the introduction of nonindigenous aquatic organisms to the coastal waters of the United States (other than the Great Lakes) and an analysis of control options*. The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6. Report No. CG-D-11-95.

Carlton, J. T., Thompson, J. K., Schemel, L. E., and Nichols, F. H. (1990). “Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis.* I. Introduction and dispersal,” *Marine Ecology Progress Series* 66, 81-94.

Clark, P. F., Rainbow, P. S., Robbins, R. S., Smith, B., Yeomans, W. E., Thomas, M., and Dobson, A. G. (1998). “The alien Chinese Mitten Crab, *Eriocheir sinensis* (Crustacea: Decapoda: Brachyura), in the Thames catchment,” *Journal of the Marine Biological Association of the United Kingdom* 78, 1215-1221.

Cohen, A. N. (2004). *An exotic species detection program for Tillamook Bay*. Tillamook Estuaries Partnership, Garibaldi, OR and U.S. Environmental Protection Agency, National Estuary Program. Available online at *http://www.sfei.org/bioinvasions/Reports/2004-TillamookBayESDP379.pdf*.

Cohen, A. N., and Carlton, J. T. (1995). *Biological Study. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta.* A report for the United States Fish and Wildlife Service, Washington, DC and the National Sea Grant Program, Connecticut Sea Grant Publication PB96-166525. Available online at *http://www.anstaskforce.gov/sfinvade.htm*.

Cohen, A. N., Berry, H. D., Mills, C. E., Milne, D., Britton-Simmons, K., Wonham, M. J., Second, D. L., Barkas, J. A., Bingham, B., Bookheim, B., Byers, J. E., Chapman, J. W., Cordell, J. R., Dumbald, B., Fukuyama, A., Harris, L., Kohn, A., Li, K., Mumford, T., Radashevsky, V., Sewall, A. and Welch, K. (2001b). *Washington State Exotics Expedition 2000: A Rapid Survey of Exotic Species in the Shallow Waters of Elliot Bay, Totten and Eld Inlets, and Willapa Bay*. The Nearshore Habitat Program, Washington State Department to Natural Resources, Olympia, WA. Available online at *http://www.sfei.org/bioinvasions/Reports/2002-2000SoCalifsurvey_384.pdf*.

Cohen, A. N., Carlton, J. T., and Fountain, M. C. (1995). "Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California," *Marine Biology* 122, 225-237.

Cohen, A. N., Weinstein, A., Emmett, M. A, Lau, W., and Carlton, J. T. (2001a). *Investigations into the Introduction of Non-indigenous Marine Organisms via the Cross-Continental Trade in Marine Baitworms.* Report to United States Fish and Wildlife Service, San Francisco Bay Program, Sacramento, CA. Available online at *http://www.sfei.org/bioinvasions*.

Cordell, J. R., and Morrison, S. M. (1996). "The invasive Asian copepod *Pseuodiaptomus inopinus* in Oregon, Washington, and British Columbia estuaries," *Estuaries* 19, 629-638.

Cordell, J. R., and Rassmussen, M. (2001). "An exotic copepod in Pacific Northwest estuaries." *Second International Conference on Marine Bioinvasions. April 9-11, 2001. New Orleans, LA.* Available online at *http://massbay.mit.edu/exoticspecies/conferences/2001*.

Crooks, J. A. (1996). "The population ecology of an exotic mussel, *Musculista senhousia*, in a Southern California bay," *Estuaries* 19: 42-50.

Crooks, J. A. (1998). "Habitat alteration and community-level effects of an exotic mussel, *Musculista senhousia*," *Marine Ecology Progress Series* 162, 137-152.

Crooks, J. A., and Khim, H. S. (1999). "Architectural vs. biological effects of a habitat-altering, exotic mussel, *Musculista senhousia*," *Journal of Experimental Marine Biology and Ecology* 240, 53-75.

DeWitt, T. H., and Levinton, J. S. (1985). "Disturbance, emigration, and refugia: How the mud snail *Ilynassa obsoleta* (Say), affects the habitat distribution of an epifaunal amphipod, *Microdeuptopus gryllotalpa* (Costa)," *Journal of Experimental Marine Biology and Ecology* 92, 97-113.

Dudas, S. E., McGaw, I. J., and Dower, J. F. (2003). "Foraging behavior of two crab species on native and non-indigenous bivalves in coastal British Columbia." *Third International Conference on Bioinvasions. March 16-19, 2003, Scripps Institution of Oceanography, La Jolla, CA.* Available online at *http://massbay.mit.edu/exoticspecies/conferences/2003/index.html*.

Dunn, R., Mullineaux, L. S., and Mills, S. W. (1999). "Resuspension of postlarval soft-shell clams *Mya arenaria* through disturbance by the mud snail *Ilynassa obsoleta*," *Marine Ecology Progress Series* 180, 223-232.

Eldredge, L. G., and Evenhuis, N. L. (2002). "Numbers of Hawaiian species for 2000," Records of the Hawaii Biological Survey for 2000. *Bishop Museum Occasional Papers* 68, 71-78.

Elston, R. (1997). *Pathways and management of marine nonindigenous species in the shared waters of British Columbia and Washington*. Puget Sound Action Team. Available online at *http://www.psat.wa.gov/shared/nis.html*.

Erlich, P. R. (1989). "Attributes of Invaders and the Invading Processes: Vertebrates." *Biological Invasions: A Global Perspective.* J. A. Drake et al., ed., 1989 SCOPE. John Wiley and Sons, Ltd. Available online at *http://www.icsu-scope.org/downloadpubs/ scope37/scope37.html*.

Federal Register. (1999). Executive Order 13112 of February 3, 1999—Invasive Species. Federal Register 64, No. 25. Available online at *http://www.invasivespecies.gov/laws*.

Feller, R. (1984). "Dietary immunoassay of *Ilyanassa obsoleta* the eastern mud snail," *Biological Bulletin* 166, 96-102.

Feyrer, F., Herbold, B., Matern, S., and Moyle, P. B. (2003). "Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary," *Environmental Biology of Fishes* 67, 277-288.

Glude, J. B. (1955). "The effects of temperature and predators on the abundance of the soft-shell clam, *Mya arenaria*, in New England," *Transactions of the American Fisheries Society* 84, 13-24.

Gray Hitchcock, N., Teck, S., Lipski, D., Steves, B., de Rivera, C. and Ruiz, G. (2003). "Predicting European green crab, *Carcinus maenas*, invasion in Alaska." *Third International Conference on Bioinvasions. March 16-19, 2003*. Available online at *http://massbay.mit.edu/exoticspecies/conferences/2003*.

Grosholz, E., and Ruiz, G. (eds.) (2002). "Management plan for the European green crab," Submitted to the Aquatic Nuisance Species Task Force. March 1, 2002. Available online at *http://anstaskforce.gov/*.

Grosholz, E. D., and Ruiz, G. M. (1995). "Spread and potential impact of the recently introduced European green crab *Carcinus maenas*, in Central California," *Marine Biology* 122, 239-247.

Grosholz, E. D., Ruiz, G. M., Dean, C. A, Shirley, K. A., Maron, J. L., and Connors, P. G. (2000). "The impacts of a nonindigenous predator in a California bay," *Ecology* 81, 1206-1224.

Hanson, E. and Sytsma, M. (2001) *Oregon Aquatic Nuisance Species Management Plan.* Portland State University, Portland, OR. Available online at *http://www.anstaskforce.gov/OR_ANS_Plan.pdf*.

Highley, T. L. (1999)."Biodeterioration of wood." *Wood handbook--Wood as an engineering material.* Gen. Tech. Rep. FPL-GTR-113, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI. Available online at *http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch13.pdf*.

Hines, A. H., and Ruiz, G. M. (2000). *Biological invasions of cold-water coastal ecosystems: Ballast-mediated introductions in Port Valdez/Prince William Sound, Alaska*. Prince William Sound Regional Advisory Board, Valdez, AK. Available online at *http://www.pwsrcac.org/NIS/pws.html#biological*.

Hines, A. H., and Ruiz, G. M. (2001). *Marine invasive species and biodiversity of South Central Alaska*. Prince William Sound Regional Advisory Board, Valdez, AK. Available online at *http://www.pwsrcac.org/NIS/pws.html#biological*.

Hoagland, K. E. (1983). " Life history characteristics and physiological tolerances of *Teredo bartschi*, a shipworm introduced into two temperate zone nuclear power plant effluents." Hemisphere Publishing Co., Miami Beach, FL.

Hunt, J. H., Ambrose, W. G., and Peterson, C. H. (1987). "Effects of the gastropod, *Ilyanassa obsoleta* (Say), and the bivalve, *Mercenaria mercenaria* (L.), on larval settlement and juvenile recruitment of infauna," *Journal of Experimental Marine Biology and Ecology* 108, 229-240.

Kelaher, B. P., Levinton, J. S., and Hoch, J. M. (2003). "Foraging by the mud snail *Ilyanassa obsoleta* (Say), modulates spatial variation in benthic community structure," *Journal of Experimental Marine Biology and Ecology* 292, 139-157.

Kimmerer, W. J., Gartside, E., and Orsi, J. J. (1994). “Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay,” *Marine Ecology Progress Series* 113, 81-93.

Kozloff, E. N. (1983). *Seashore Life of the Northern Pacific Coast. An Illustrated Guide to Northern California, Oregon, Washington, and British Columbia.* University of Washington Press, Seattle, WA.

Lavoie, D. M., Smith, L. D., and Ruiz, G. M. (1999). “The potential for intracoastal transfer of nonindigenous species in the ballast water of ships,” *Estuarine, Coastal and Shelf Science* 48, 551-654.

McDonald, P. S., Jensen, G. C., and Armstrong, D. A. (2001). “The competitive and predatory impacts of the nonindigenous crab *Carcinus maenas* (L.) on early benthic phase Dungeness crab *Cancer magister* Dana,” *Journal of Experimental Marine Biology and Ecology* 258, 39-54.

Meng, L., and Orsi, J. J. (1991). Elective predation by larval Striped bass on native and introduced copepods,” *Transactions of the American Fisheries Society* 120, 187-192.

Miller, T. W. (1996). “First record of the green crab *Carcinus maenas* in Humboldt Bay, California,” *California Fish and Game* 82, 93-96.

Mills, C. E. (2002). “*Nuttallia obscurata*, the purple varnish clam or the purple mahogany-clam.” Available online at *http://faculty.washington.edu/cemills/Nuttallia.html*.

Mills, C. E. (2003). “Commentary on species of hydrozoa, scyphozoa, and anthozoa (*Cnidaria*) sometimes listed as non-indigenous in Puget Sound.” Available online at *http://faculty.washington.edu/cemills/PScnidaria.html*.

Moksnes, P.-O. (2002). “The relative importance of habitat-specific settlement, predation, and juvenile dispersal for distribution and abundance of young juvenile shore crabs *Carcinus maenas* L,” *Journal of Experimental Marine Biology and Ecology* 271, 41-73.

Nichols, F. H., Thompson, J. K., and Schemel, L. E. (1990). “Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis.* II. Displacement of a former community,” *Marine Ecology Progress Series* 66, 81-94.

Pace, M. L., Shimel, S., and Darley, W. M. (1979). “The effect of grazing by a gastropod, *Nassarius obsoletus*, on the benthic microbial community of a salt marsh mudflat,” *Estuarine and Coastal Marine Science* 9, 121-134.

Padilla, D. K., and Williams, S. L. (2004). “Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems,” *Frontiers in Ecology and the Environment* 3, 131-138.

Pihl, L. (1985). “Food selection and consumption of mobile epibenthic fauna in shallow marine areas,” *Marine Ecology Progress Series* 22, 169-179.

Race, M. S. (1982). “Competitive displacement and predation between introduced and native mud snails,” *Oecologia* 54, 337-347.

Ray, G. L. (2005) “Invasive animal species in marine and estuarine environments: Biology and ecology,” Technical Report ERDC/EL TR-05-2, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Reutsch, T. B. H., and Williams, S. L. (1998). “Variable response of native eelgrass *Zostera marina* to a nonindigenous bivalve *Musculista senhousia*,” *Oecologia* 113, 428-441.

Roach, J. (2004). “Seattle waterfront falling to gribble invasion,” *National Geographic News*. Available online at *http://news.nationalgeographic.com/news/2004/04/0423_040423_gribbles.html*.

Ropes, J. W. (1968). “The feeding habits of the green crab, *Carcinus maenas* (L.),” *Fishery Bulletin* 67, 183-203.

Ross, D. J., Johnson, C. R., Hewitt, C. L. and Ruiz, G. M. (2004). “Interaction and impacts of two introduced species on a soft-sediment marine assemblage in SE Tasmania,” *Marine Biology* 144, 747-756.

Ruiz, G. M., Fofonoff, P., Carlton, J. T., Wonham, M. J., and Hines, A. H. (2000). “Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases,” *Annual Review in Ecology and Systematics* 2000, 481-531.

Scattergood, L. W. (1952). “The distribution of the green crab *Carcinides maenas* (L.), in the Northwestern Atlantic,” Maine Department of Sea Shore Fisheries. *Fishery Circular* 8, 2-10.

Scheltema, R. S. (1964). “Feeding habits and growth in the mud-snail *Nassarius obsoletus* ,” *Chesapeake Science* 5, 161-166.

State of Alaska. (2002). *Alaska Aquatic Nuisance Species Management Plan.* State of Alaska, Department of Fish and Game, Juneau, AK. Available online at *http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf*.

State of Washington (2001). *Aquatic Nuisance Species Management Plan.* Washington Department of Fish and Wildlife, Olympia, WA. Available online at *http://www.wdfw.wa.gov/fish/nuisxsum.htm*.

Talley, T. S., Crooks, J. A., and Levin, L. A. (2001). “Habitat utilization and alteration by the invasive, burrowing isopod, *Sphaeroma quoyanum*, in California salt marshes,” *Marine Biology* 138, 561-573.

Torchin, M. E., Lafferty, K. D., Dobson, A. P., McKensie, V. J. and Kuris, A. M. (2003). “Introduced species and their missing parasites,” *Nature* 421, 628-630.

Veldhuizen, T., and Stanish, S. (2002). “Overview of the life history, distribution, abundance, and impacts of Chinese mitten crab *Eriocheir sinensis*.” *A Draft National Management Plan for the Genus Eriocheir*. Aquatic Nuisance Species Task Force. February 2002. 37-5. Available online at *http://anstaskforce.gov/*.

Vernberg, W. B., and Vernberg, F. J. (1975). “The physiological ecology of larval *Nassarius obsoletus* (say).” *Proceedings of the 9th European Marine Biology Symposium*, H. Barnes, ed., Aberdeen University Press, Aberdeen, UK, 179-190.

Volpe, J. P. (2001). *Super un-Natural. Atlantic Salmon in BC Waters.* David Suzuki Foundation, Vancouver, British Columbia.

Volpe, J. P., Anholt, R., and Glickman, B. W. (2001). “Competition among juvenile Atlantic salmon (*Salmo salar*) and steelhead (*Oncorhynchus mykiss*): relevance to invasion potential in British Columbia,” *Canadian Journal of Fisheries and Aquatic Science* 58, 197-207.

Volpe, J. P., Taylor, E. B., Rimmer, D. W., and Glickman, B. W. (2000). “Evidence if natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia river,” *Conservation Biology* 14, 899-903.

Walton, W. C., MacKinnon, C., Rodriguez, L. F., Proctor, C. and Ruiz, G. M. (2002). “Effect of an invasive crab on a marine fishery: Green crab, *Carcinus maenas*, predation upon a venerid clam, *Katelysia scalarina*, in Tasmania (Australia),” *Journal of Experimental Marine Biology and Ecology* 272, 171-189.

Washington Department of Fish and Wildlife. (2004). *Fisheries Potential of the Purple Varnish Clam (Nuttallia obscurata*). Aquatic Nuisance Species fact sheet. Available online at *http://www.wdfw.wa.gov/fish/ans/varnishclams.htm*.

Weigle, S. M., Smith, L. D., Carlton, J. T. and Pederson, J. (2005). “Assessing the risk of introducing exotic species via the live marine species trade,” *Conservation Biology* 19, 213-223.

Werner, I., and Hollibaugh, J. T. (1993). “*Pomatocorbula amurensis*: Comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton,” *Limnology and Oceanography* 38, 949-964.

Williams, J. D., and Meffe, G. K. (1999). "Nonindigenous species." *Status and trends of the Nation's biological resources.* United States Geological Service. Available online at *http://biology.usgs.gov/s+t/SNT/index.htm*.

Wing, B. L., Guthrie, C. M., and Gharrett, A. J. (1992). "Atlantic salmon in marine waters of Southeastern Alaska," *Transactions of the American Fisheries Society* 121, 814-818.

Wolfe, L. M. (2002). "Why alien invaders succeed: support for the escape-from-enemy hypothesis," *American Naturalist* 160, 705-711.

Wonham, M. J., and Carlton, J. T. (2005). "Trends in marine biological invasions at local and regional scales: The Northeast Pacific Ocean as a model system," *Biological Invasions* 7, 369-392.

Yamada, S. B., Kalin, A. and Hunt, C. (2001). "Growth and longevity of the European green crab *Carcinus maenas*, in the Pacific Northwest." *Second International Conference on Bioinvasions, 2001, New Orleans, LA.* Available online at *http://massbay.mit.edu/exoticspecies/conferences/2001*.

Zachary, A., Parrish, K. K., and Bultman, J. D. (1983). Possible role of marine bacteria in providing the creosote-resistance of *Limnoria tripunctata*," *Marine Biology* 75, 1-8.

APPENDIX A: NIS LISTINGS BY STATE FOR THE PACIFIC NORTHWEST AND ALASKA

Species	Group	WA	OR	AK
Trochammina hadai	Protozoan	WA	OR	
Blackfordia virginica	Hydrozoan		OR	
Bouganvillia muscus	Hydrozoan	WA		
Clava sp.	Hydrozoan		OR	
Cladonema radiatum	Hydrozoan	WA		
Corydolophora caspia	Hydrozoan	WA	OR	
Ectopleura (Tubularia) crocea	Hydrozoan	WA	OR	AK
Gonothyraea clarki	Hydrozoan		OR	
Obelia sp.	Hydrozoan	WA	OR	
Aurelia aurita	Schyphozoan	WA		
Clathria prolifera	Porifera	WA		
Clionoa thoosina	Porifera	WA		
Cliona sp.	Porifera	WA	OR	AK
Halichondria bowerbanki	Porifera	WA	OR	
Haliclona loosanoffi	Porifera		OR	
Haliclona luciae	Porifera	WA		
Microciona prolifera	Porifera	WA		
Diadumene lineata	Anthozoan	WA	OR	AK
Diadumene leucolema	Anthozoan		OR	
Nematostella vectensis	Anthozoan		OR	
Cercaria batillariae	Platyhelminth	WA		
Pseudostylochus ostreaphagus	Platyhelminth	WA		
Hobsonia (Amphicteis) florida	Polychaete	WA	OR	
Capitella capitata	Polychaete	WA		
Capitella spp.	Polychaete	WA	OR	
Capitomastus sp.	Polychaete		OR	
Eteone tchangsii	Polychaete		OR	
Eteone sp.	Polychaete		OR	
Fabricia sabella	Polychaete		OR	
Harmothoe imbricata	Polychaete		OR	
Heteromastus filiformis	Polychaete	WA	OR	AK
Manayunkia aestuarina	Polychaete		OR	
Manayunkia speciosa	Polychaete		OR	AK
Nereis (Neanthes) succinea	Polychaete	WA	OR	
Owenia fusiformis	Polychaete		OR	
Pionospyllis uraga	Polychaete	WA		
Polydora cornuta	Polychaete	WA	OR	
Pseudopolydora kempi	Polychaete	WA	OR	
Pseudopolydora paucibranchiata	Polychaete	WA	OR	
Pygpspio elegans	Polychaete	WA		
Sabaco elongates	Polychate	WA		

(Sheet 1 of 4)

Species	Group	WA	OR	AK
Streblospio benedicti	Polychaete	WA	OR	
Thayrx tesselata	Polychaete	WA		
Limnodrilus monothecus	Oligochaete	WA		
Paranais frici	Oligochaete	WA	OR	
Tubificoides apectinatus	Oligochaete	WA		
Tubificoides brownae	Oligochaete		OR	
Tubificoides diazi	Oligochaete		OR	
Tubificoides wasselli	Oligochaete	WA		
Crassostrea gigas	Bivalve	WA	OR	AK
Crassostrea rivularis	Bivalve	WA		
Crassostrea virginica	Bivalve	WA		
Gemma gemma	Bivalve	WA		
Mercenaria mercenaria	Bivalve	WA		
Meretrix lusoria	Bivalve	WA		
Musculista senhousia	Bivalve	WA		
Mya arenaria	Bivalve	WA	OR	AK
Mysella tumida	Bivalve	WA		
Mytilus edulis	Bivalve	WA		
Mytilus galloprovincialis	Bivalve	WA	OR	
Neotrapezium liratum	Bivalve	WA		
Nuttallia obscurata	Bivalve	WA	OR	
Ostrea edulis	Bivalve	WA		
Petricola pholadiformis	Bivalve	WA		
Teredo navalis	Bivalve	WA	OR	
Venerupis (Tapes) philippinarum	Bivalve	WA	OR	
Batillaria (zonalis) attramentaria	Gastropod	WA		
Cecina manchurica	Gastropod	WA		
Collisella striata	Gastropod	WA		
Crepidula convexa	Gastropod	WA		
Crepidula fornicata	Gastropod	WA		
Crepidula plana	Gastropod	WA		
Cumanotus beaumonti	Gastropod	WA	OR	
Haliotis rufescens	Gastropod	WA		
Littorina brevicula	Gastropod	WA		
Littornia littorea	Gastropod	WA		
Melanoides tubercuatus	Gastropod		OR	
Monodonta labio	Gastropod	WA		
Myostella myoostis	Gastropod	WA	OR	
Nassarius fraticularis	Gastropod	WA		
Nassarius obsoletus	Gastropod	WA		
Neptunea arthrictica	Gastropod	WA		
Ocenebra japonica	Gastropod	WA		
Ocinebrellus (Ceratoasotma) inornatus	Gastropod	WA	OR	
Philine auriformis	Gastropod		OR	
Purpura clavigera	Gastropod	WA		
				(Sheet 2 of 4)

Species	**Group**	**WA**	**OR**	**AK**
Radix auricularia?	Gastropod	WA		
Rapana thomasiana	Gastropod	WA		
Rapana venosa	Gastropod	WA		
Thais clavigera	Gastropod	WA		
Turbo marmoratus	Gastropod	WA		
Turbo sornatus coreensis	Gastropod	WA		
Urosalpinx cinerea	Gastropod	WA		
Tenellia aspersa	Nudibranch		OR	
Acanthichitona achaetes	Chiton	WA		
Balanus improvisus	Barnacle	WA	OR	
Argulus japonicus	Copepod	WA		
Coullana candensis	Copepod		OR	
Eurytemora affinis	Copepod		OR	
Limnoithona sinensis	Copepod	WA	OR	
Paramisophria sp.	Copepod	WA		
Pseudomyicola (Myticola orientalis) ostreae	Copepod	WA	OR	
Pseudodiamptomus forbesi	Copepod		OR	
Pseudodiaptomus marinus	Copepod	WA		
Pseudodiaptomus inopinus	Copepod	WA	OR	
Ampithoe valida	Amphipod	WA	OR	
Caprella mutica	Amphipod	WA	OR	
Chelura terebrans	Amphipod	WA		
Monocorophium acherusicum	Amphipod	WA	OR	
Monocorophium insidiosum	Amphipod	WA	OR	
Eobrolgus spinosus	Amphipod		OR	
Eochelidium sp.	Amphipod	WA		
Grandidierella japonica	Amphipod	WA	OR	
Jassa marmorata	Amphipod	WA	OR	
Melita nitida	Amphipod	WA	OR	
Iinciscalliope (Parapleustes) derzhavini	Amphipod	WA	OR	
Caecidotea racovitzai	Isopod		OR	
Iais californica	Isopod	WA	OR	
Limnoria tripunctata	Isopod		OR	
Sphaeroma quoyanum	Isopod	WA		
Synidotea laevidorsalis	Isopod	WA		
Leptochelia dubia	Tanaid		OR	
Sinelobus stanfordi	Tanaid	WA	OR	
Tanais sp.	Tanaid	WA		
Nippoleucon hinumensis	Cumacean	WA	OR	
Carcinus maenas	Crab	WA	OR	
Eriocheir japonicus	Crab	WA	OR	
Eriocheir sinensis	Crab	WA		
Rithropanopeus harrisi	Crab		OR	
Crangon pseudogracilis	Shrimp		OR	
Palaemon macrodactylus	Shrimp		OR	
				(Sheet 3 of 4)

Species	Group	WA	OR	AK
Exopalaemon modestus	Shrimp	WA	OR	
Homarus americanus	Lobster	WA		
Alcyonidium polyoum	Bryozoan		OR	
Alcyonidium sp.	Bryozoan		OR	
Bowerbankia gracilis	Bryozoan	WA	OR	
Bugula neritina	Bryozoan	WA	OR	
Bugula stolonifera	Bryozoan	WA		
Conopeum tenuissimum	Bryozoan		OR	
Cryptosula pallasiana	Bryozoan	WA	OR	
Schizoporella unicornis	Bryozoan	WA	OR	
Triticella sp.	Bryozoan		OR	
Watersipora "subtorquata"	Bryozoan		OR	
Barentsia benedini	Entoproct	WA	OR	AK
Botrylloides violaceus	Tunicate	WA	OR	AK
Botryllus schosseri	Tunicate	WA	OR	
Botryllus sp.	Tunicate			AK
Ciona intestinalis	Tunicate	WA		
Ciona savignyi	Tunicate	WA		
Didemnum cf. lahillei	Tunicate	WA		
Diplosoma lsiterianum	Tunicate		OR	
Mogula manhattensis	Tunicate	WA	OR	
Styela clavata	Tunicate	WA	OR	
Alosa sapidissima	Fish	WA	OR	
Anguilla sp.	Fish		OR	AK
Dorosoma petenense	Fish		OR	
Gambusia affinis	Fish	WA	OR	
Lucania parva	Fish		OR	
Morone saxatilis	Fish	WA	OR	
Oncorhtynchus kisutch	Fish	WA	OR	
Salmo salar	Fish	WA	OR	AK
				(Sheet 4 of 4)